Natural Sciences 102 Problem Set 5 Solutions

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Problem 2

a) The assistant have to observe the apparent magnitudes and the color of the stars. The observational HR diagram is the plot of the apparent magnitude against the color.

b)We can compare the HR diagram of a nearby cluster with the HR diagram of Rocky II to get the distance to Rocky II, provided that both HR curves have the same shape. If they have the same shape, that means they are similar clusters. Each star at the same color has the same luminosity for both clusters. Since nearby cluster is closer to us, therefore its stars are brighter, and their apparent magnitudes are less than those in Rocky II, and this is represented as a downward shift in magnitude in the HR diagram. The change in magnitude gives us the difference in distance between the two clusters:

$$m_{RockyII} - m_{nearby} = -2.5log(I_{RockyII}/I_{nearby})$$

From the relationship between intensity, luminoity, and distance, we have

$$\begin{aligned} I_{RockyII} &= \frac{L_{RockyII}}{4\pi r_{RockyII}^2} \\ I_{nearby} &= \frac{L_{nearby}}{4\pi r_{nearby}^2} \end{aligned}$$

Since

$$L_{nearby} = L_{RockyII}$$

therefore

$$\frac{I_{RockyII}}{I_{nearby}} = \left(\frac{r_{nearby}}{r_{RockyII}}\right)^2$$

Substituting it back in the first equation, we get a relationship between the difference in magnitude and the difference in distances:

$$\begin{aligned} m_{RockyII} - m_{nearby} &= -5log\left(\frac{r_{nearby}}{r_{RockyII}}\right) \\ r_{RockyII} &= r_{nearby} \times 10^{(m_{RockyII}-m_{nearby})/5} \end{aligned}$$

The distance to Rocky II is known once we know the distance to the nearby clusterby, say, parallax.

Problem 3

Answer: Having found the period of the Cepheid star and the apparent magnitude $m_{M137} = 20$ magnitudes, since we know that we can use it as a standard candle, we can use the data from another set of stars (in this case the LMC) and then apply that to calculate the distance to M137.

We know the period is 10 days, and that corresponds in the LMC to an apparent magnitude of approximately $m_{LMC} = 15$ magnitudes. We also know the distance to the LMC, $d_{LMC} = 50$ kpc. Then, using the formula that relates two magnitudes:

$$m_1 - m_2 = -2.5 \log\left(\frac{I_1}{I_2}\right) \tag{1}$$

we can find, if $m_1 = m_{LMC}$ and $m_2 = m_{M137}$, then

$$m_{LMC} - m_{M137} = -5 \Rightarrow \frac{I_{LMC}}{I_{M137}} = 100. \tag{2}$$

Then, knowing the Cepheid stars with the same period have same luminosity (standard candle)

$$I = \frac{L}{4\pi d^2} \Rightarrow \frac{I_{LMC}}{I_{M137}} = \left(\frac{d_{M137}}{d_{LMC}}\right)^2 \tag{3}$$

then, we solve for d_{M137}, getting that M137 is approximately 500 kpc away.